Study on Respiration-synchronous Irraddiation in the Spot-beam Scanning Technique

IV. 1. Study on Respiration-synchronous Irradiation in the Spot-beam Scanning Technique

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The spot-beam scanning irradiation in charged-particle therapy provides a three-dimensional dose distribution which agrees with the tumor shape without high level dose in the surrounding normal tissue. The scanning technique has currently been limited in treatment for cancers having no respiration movement because the beam control is highly sensitive to the target movement.

We have developed respiration-synchronous operation system in the spot-beam scanning technique by using the horizontal beam irradiation facility[1)] for proton therapy experiments. The respiration-synchronous irradiation needs the measurement of displacement of the cancer position due to the respiration. If a relationship in the respiration movements between the body surface and an organ is obtained, it would be possible to monitor the displacement of the cancer position in the organ from that of the body surface.

We performed the experimental study on the respiration-synchronous beam-scanning method with a moving target. In order to evaluate the relationship between the surface and the organ movements, the motions of the surface and liver of a dog were measured[2)] from X-ray transmission images with gold markers at Veterinary Teaching Hospital, Kitasato University as shown in Fig. 1. The results show no significant difference in phase between their periodical movements.

The experiments were performed using an 80-MeV proton as an incident spot beam and a moving target which simulates the movement of the body surface in the lateral directions as shown in Fig. 2, whereas two laser rangers were used for measuring the

displacement of the target position in the horizontal and vertical directions. The irradiation was allowed at the end of breathing because there were little changes in the positions of both the surface and the organ.

In Fig. 3, the experimental results for the lateral intensity distributions by the spot-beam scanning technique with the synchronous irradiation are shown and compared with those without the synchronous operation. The dose distribution was measured with an Imaging Plate[3)] attached to the moving target. We confirmed that the irradiation fields were successfully generated in the case of the synchronous operation, whereas the non-synchronous irradiation provided unnecessary dose outside the target region. The depth-dose distribution by the scanning technique is also in good agreement with the simulation as shown in Fig. 4.

References

1) Terakawa A., et al., CYRIC Annual Report (2006) 41.
2) Houdatsu T., a graduation thesis (2007), School of Veterinary Medicine and Animal Sciences, Kitasato University
3) Fuji Photo Film Co., Ltd.

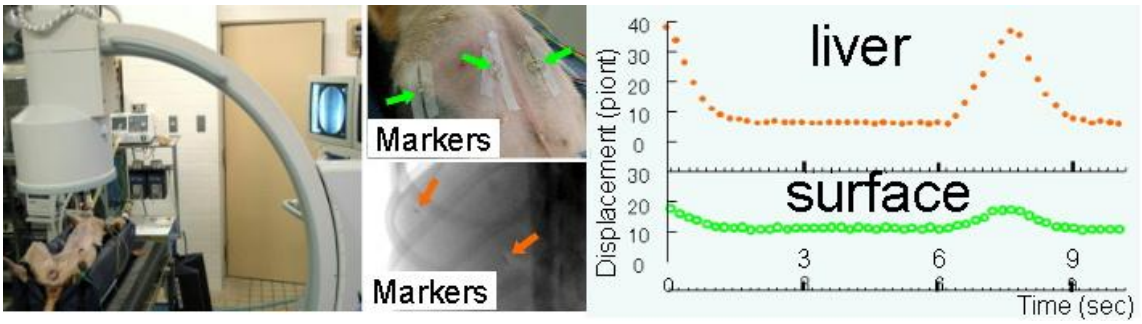

Figure 1. Respiration motion measurements[2)] for the body surface and the organ of a dog.

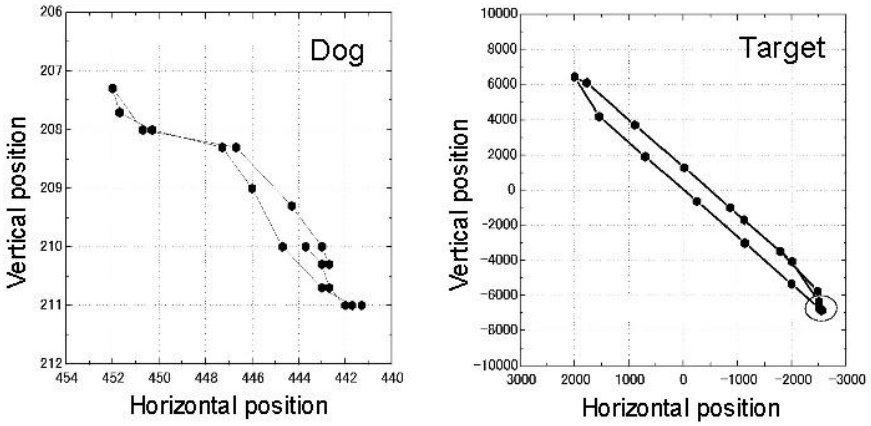

Figure 2. Respiration movements of the body surface of a dog and the simulated movement of the target. The frequency of dog's respiration controlled by anesthesia is 8 s^{-1}. The circle in the graph for the target indicates the area in which the irradiation is allowed.

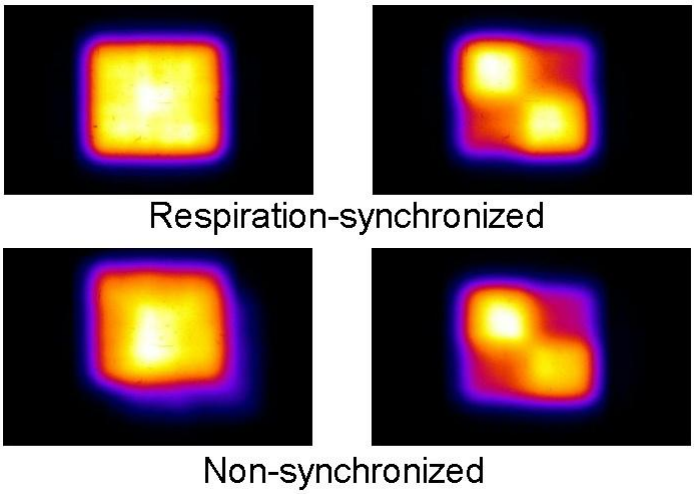

Figure 3. Lateral irradiation fields for the moving target with and without the respiration-synchronous operation.

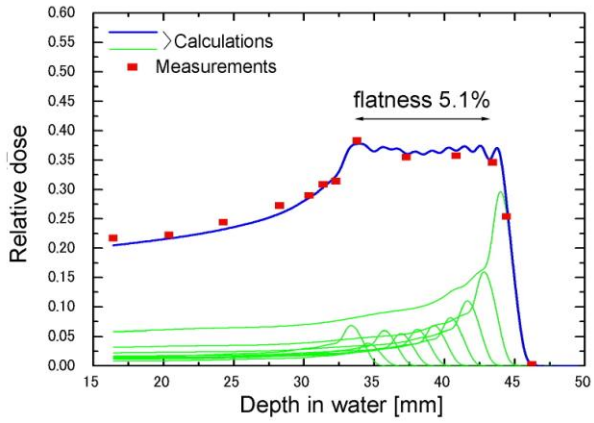

Figure 4. Depth-dose distribution (spread-out Bragg peak) provided by the spot-beam scanning technique with the range-shifter.